Influence of Protein Intake on Maternal Weight Gain and Infant Birth Weight Across Pregnancy

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Abstract

Protein and amino acid intake during pregnancy appears to influence gestational weight gain (GWG). Nutrient intake and GWG have been linked to birth weight, respectively, with little evidence of the temporal effects. The purpose of this study was to examine maternal protein and amino acid intake on gestational weight gain (GWG) and birth outcomes across pregnancy. Prospectively, we collected dietary intake data from nulliparous women (n=52) during each trimester. We correlated maternal protein and amino acid intake with the defined pregnancy outcomes. We analyzed group differences for total GWG (≤19 lbs. [n=17], ≥25 lbs. [n=18]), 1st to 2nd trimester GWG (≤7 lbs. [n=16], ≥12 lbs. [n=18]), 2nd to 3rd trimester GWG (≤10 lbs. [n=17], ≥16 lbs. [n=18]) and infant birth weight (≤3000g [n=15], ≥3500g [n=21]). Significance was determined at ($p<0.05$). Among the amino acids (18), there was a marginal correlation between second trimester cystine intake and infant birth weight ($p=0.06$), as well as group differences ($p=0.06$). There was no correlation between maternal dietary protein intake and GWG across pregnancy. There were no group differences in protein or amino acid intake for total weight gain, weight gain by trimester or infant birth weight. Maternal dietary protein intake exceeded the recommended 71 g/day for pregnancy limiting ability to determine impact on birth outcomes. Future studies examining variable cysteine intake in pregnancy may identify influence on infant birth weight during critical periods of development.

Keywords: Gestational Weight Gain, Protein Intake, Birth Weight, Nulliparous

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The incidence of diet-related chronic diseases and health problems has been argued to be one of greatest threats to public health in the United States (Cordain et al., 2005). More than one-third of U.S. adults are obese (Ogden, Carroll, Kit, & Flegal, 2014). The Western diet, also known as the standard American diet (SAD) is marked by excess sodium intake from mainly processed foods and excessive consumption of refined carbohydrates, fatty meats, and added fat. In addition to this increased calorie intake, the SAD is also lacking in lean protein, whole grains, fruits and vegetables which supply many vitamins and nutrients (Grotto & Zied, 2010). Furthermore, Americans are living a more sedentary lifestyle. This overall dietary pattern combined with a sedentary lifestyle contributes weight gain. (World Health Organization [WHO], 2003).

Proper nutrition is necessary to support overall wellness across all life stages, including pregnancy. Dietary intake of macronutrients including fat, protein, and carbohydrates all contribute to fuel for the body as caloric energy. An imbalance between this dietary caloric intake and energy expenditure results in a positive caloric balance which may contribute weight gain based on individual absorption and metabolism.

Optimal maternal nutrition promotes maternal health and fetal development during pregnancy. Rodriguez & Miller (2015) suggest there is sufficient evidence to support dietary protein intake as a means to control body weight. They also suggest protein should be within the 10-35% of one's daily caloric intake. This provides a range with a higher upper limit than current recommended intakes to encourage an increase in dietary protein. Recommendations for

macronutrient intake, as well as other components of the diet, are set during pregnancy because the needs of a woman differ throughout gestation. This is due to the unique physiological changes and nutritional requirements of the mother and baby compared to the needs of non-pregnant women of similar age. Factors influencing the nutritional requirements of the mother and fetus include the specific needs of the fetus during pregnancy, biological adaptive processes which increase nutritional requirements (i.e. increased absorption and conservation of many nutrients) and an overall nutritional deficiency, despite adequate intake, related to physiological mechanisms (Institute of Medicine [IOM], 2006).

Protein is one of the three dietary macronutrients and forms the major structural components of all the cells of the body. Proteins also function as enzymes, in membranes, as transport carriers, and as hormones. Amino acids are the monomer components of protein and combine to form nucleic acids, hormones, vitamins, and other fundamental compounds. Thus, an adequate supply of dietary protein is essential to maintain cellular integrity and function, and for health and reproduction (IOM, 2006).

One measure of maternal nutrition is weight gain across pregnancy. Maternal behavioral factors including dietary intake of protein may be a potential determinant for gestational weight gain (GWG) and pregnancy outcomes (Wycherley, Moran, Clifton, Noakes, & Brinkworth, 2012; Imdad & Bhutta, 2011). Gestational weight gain is a complex biological process that aides in fetal growth and development as a result of changes in maternal physiology and metabolism, as well as placental metabolism. As pregnancy progresses, protein, fat, water, and minerals are deposited in the fetus, placenta, amniotic fluid, uterus, mammary gland, blood, and adipose tissue. “The products of conception (placenta, fetus, amniotic fluid) comprise approximately 35

percent of the total GWG" (as cited in IOM, 2009, p. 77). Both excessive and inadequate weight gain during pregnancy may influence pregnancy outcomes including infant birthweight (Siega-Riz et al., 2009).

Background of the Problem

Although there is evidence based literature surrounding many topics of pregnancy, the contemporary population of American women is becoming increasingly diverse. This suggests a need for new knowledge to support the changing demographic. Their biometric distribution is changing as well. Women today weigh more and a larger percentage are entering pregnancy overweight or obese, with many gaining weight excessively during pregnancy. These changes are accompanied by chronic disease, which can put the health of both the mother and baby at risk (Institute of Medicine [IOM], & National Research Council 2009). All of these factors require the continuing evaluation of the standards and guidelines for a healthy pregnancy.

The data sources that are currently available are insufficient for examining nationwide trends in GWG. Major gaps in GWG surveillance still remain following the IOM (1990) report which recommended more sophisticated analyses. Particularly, "data on pre-pregnancy weight and height, reliance on self-reported weight gain, and nationally representative sources are lacking" (IOM 2009). Additionally, gaps in the evidence exist for the temporal effects of GWG on birth outcomes. Thus, the purpose of this study was to examine maternal protein and amino acid intake on GWG across pregnancy and infant birth weight.

This study examines the relationship between protein intake during pregnancy and the effect on maternal weight gain across gestation and to investigate the effect of protein intake on the resulting birth weight of the fetus. By examining the correlation between protein and

pregnancy outcome measures we hope to provide new knowledge about the influence of protein intake during pregnancy as an element of optimal nutrition and thus fetal development.

The Developmental Origins of Health and Disease (DOHaD), also called the Barker Hypothesis, provided the foundation for this study which examined nutritional factors that may impact future health outcomes (Barker & Osmond, 1988; Barker, Winter, Osmond, Margetts, & Simmonds, 1989). This theoretical framework focuses on the influence of developmental factors and the future risk of non-communicable diseases in the fetus. It also points to unbalanced maternal nutrition, maternal obesity and poor fetal growth as risk factors for adverse fetal outcomes and non-communicable diseases (Hanson & Gluckman, 2015).

We seek to answer the following questions: (1) In pregnant women, does dietary intake of protein and amino acids across gestation affect total GWG? (2) In pregnant women, does dietary intake of protein and amino acids affect weight gain between trimesters? Finally, (3) in pregnant women does dietary intake of protein and amino acids across gestation affect birth weight of the fetus?

Definitions of Terms

There are terms which are essential to understand the context of this study. We define gestational weight gain (GWG) as any additional weight the mother gains during pregnancy from the point of conception to the end of the pregnancy prior to delivery. This study discusses GWG for each trimester as well as total GWG and is measured in pounds (lbs.). Macronutrients are the nutrients consumed in the diet which provide calories for energy. They include protein, fat and carbohydrates. For the purposes of this study, protein and amino acid intake was recorded in grams (g). To obtain an accurate reproductive history women are also classified by parity, or the

number of childbirths >20 weeks gestation. Nulliparous women are those with no previous childbirths (para = 0). Infant birth weight is the weight of the fetus immediately following delivery and is typically measured in pounds (lbs.) and recorded in grams (g).

Chapter II: Review of the Literature

To assess the current research available surrounding our discussion we conducted a review of the literature. This chapter reviews the current available research surrounding dietary intake and body weight in non-pregnant individuals, dietary protein and its relation to weight gain, how protein intake contributes to gestational weight gain and how gestational weight gain and protein intake affect infant birth weight.

Dietary Protein and Body Weight

To observe the effects of protein on weight gain in pregnancy, it is important to consider the effect of protein intake on body weight in non-pregnant adults. Altering intake of protein in the diet has been suggested as a method to control body weight and prevent obesity.

Leidy et al. (2015) investigated the literature on both the biochemical effects of acute protein consumption and the clinical outcomes of consuming a high-protein diet over time. They defined a higher-protein diet as one containing 1.2 to 1.6 g protein/ kg/ day that may also include an additional requirement of 25–30 g protein/ meal. Results suggested that when compared to low-protein diets, higher-protein diets help to control body weight maintenance. The long term effect was unconfirmed due to inconsistent data as result of poor dietary compliance in adults. In a systematic review and meta-analysis, Santesso et al. (2012) screened 9568 unique articles comparing health outcomes for high and low-protein diets. Search results identified 111 articles including 74 eligible studies. Health outcomes included in the studies included weight loss and change in BMI. Results suggested the benefit of higher-protein diets for weight loss for the small to moderate pooled effect sizes using standardized mean differences (SMDs). Wycherley et al.

(2012) conducted a meta-analysis of randomized controlled trials (RCTs) comparing high protein and standard protein diets that included 23 eligible studies in the quantitative synthesis out of 1282 potential articles. The high protein diet showed a greater reduction in weight compared to a standard protein diet.

In contrast, Fernandez et al. (2012) conducted a systematic review of medical literature conducted to produce evidence based dietary recommendations for the prevention and treatment of obesity in adults. There was insufficient evidence regarding the effects of total dietary protein on body weight to make a definite recommendation. Another systematic review examined the role of macronutrients, including protein, as determinants of weight change. The two eligible studies identifying the role of protein found inconsistent results with either negative or neutral association with weight gain or weight change (Fogelholm, Anderssen, Gunnarsdottir, & Lahti-Koski, 2012).

High quality systematic reviews show associations between increased protein in the diet and weight loss or maintenance. However, there is some evidence which suggests this link may not be as weak or absent.

Protein Intake During Pregnancy and GWG

After examining the effect of protein on weight gain in non-pregnant adults we reviewed the literature on the effects of protein intake on GWG. A prospective cohort study of FFQ data collected from 46,262 participants during their 25th week of pregnancy showed that high ratios of dietary protein were associated with reduced GWG (Maslova, Halldorsson, Astrup & Olsen, 2015). Conversely, a prospective study involving 270 healthy mothers in Vancouver, British Columbia, Canada collected data from food frequency questionnaires based on a 24-hour recall

at 16- and 36-week gestation. After some participants were removed from analysis based on exclusion criteria, the final analysis included 212 participants. Maternal protein consumption adjusted for body weight was significantly higher at 16-week and 36-week gestation, however, total protein intake did not differ. Protein intakes were greater than the daily recommended intake (DRI) at both 16- and 36-week gestation. Protein intakes were adjusted for body weight and a Spearman correlation was used to determine the influence of and maternal anthropometrics on pregnancy outcomes. Protein intake was positively correlated with weight gain. This study indicated higher intakes than current Dietary Reference Intakes recommended dietary allowance of 1.1 g/kg per day, especially during early gestation (Stephens, Woo, Innis & Elango, 2014).

The available studies examining the direct link between protein intake and GWG are limited. Studies that use higher levels of evidence such as meta-analyses and systematic reviews for this topic are unavailable. The studies that do exist report contradictory findings. However, the larger cohort study we identified suggested a negative association with protein intake and GWG.

GWG and Infant Birth Weight

Next, we reviewed current research to see if GWG has been linked to infant birth weight. In a systematic review focusing on infant birth weight as an outcome of GWG, Siega-Riz et al. (2009) found strong associations between excessive GWG and infant birth weight. Comparably, inadequate GWG showed strong evidence of decreased infant birth weight. Stephens et al. (2014) found that weight gain at 36 weeks gestation was positively correlated with birth weight ($P < 0.05$). In a retrospective cohort study of 5172 women, Tabatabaei et al. (2011) found that a gestational weight gain of 0.50 kg per week or greater was associated with a higher risk fetal

macrosomia ($P < 0.05$). Heude et al. (2012) also reported a strong relationship between total GWG and large for gestational age (LGA). Increasing maternal weight gain was associated with a significant decrease in risk for small for gestational age (SGA) ($P = 0.008$). An observational study of 495 Icelandic women based on food frequency questionnaires found that women who were overweight before pregnancy were more like to gain excessive weight and therefore most likely to suffer pregnancy and delivery complications. Likewise, women gaining suboptimal weight gave birth to lighter children ($P = 0.001$) and had shorter gestation ($P = 0.008$) than women gaining optimal or excessive weight (Olafsdottir, Skuladottir, Thorsdottir, Hauksson, & Steingrimsdottir, 2006).

When accounting for racial differences excessive versus adequate GWG, protection from having a SGA infant was identified in non-Hispanic white [OR = 0.64 (95% CI 0.61, 0.67)] and non-Hispanic black women [OR = 0.68 (95% CI: 0.65, 0.72)]. They also report a strong association between excessive GWG and higher infant birthweight across maternal BMI classes in non-Hispanic white and non-Hispanic black women (Hunt, Alani, Johnson, Mayorga, & Korte, 2013).

Ludwig and Currie (2010) looked at the relationship between GWG and infant birth weight within families from vital statistics data. In a final sample of 1,164,750 singleton births to 513,501 mothers GWG was consistently positively associated with infant birth weight, independent of genetic factors ($p < 0.0001$). Gender of the infant may also account for differences. Pereira-da-Silva et al. (2014) found that higher GWG was positively associated with birth weight in female infants.

Johnson et al. (2013) looked at birth outcomes with respect to the 2009 IOM guidelines and found no consistent associations with insufficient weight gain and adverse outcomes. Of 8,293 pregnancies, 9.5% had weight gain below, 17.5% within, and 73% above IOM guidelines. Normal weight and overweight women had an increased risk of infant birth weight at or above the 90th percentile but a decreased risk of weight below the 10th percentile.

The evidence suggests that there is a strong positive association between GWG and infant birth weight. However, no high-level research studies looking at this association were identified.

Protein Intake and Infant Birth Weight

Finally, we reviewed current knowledge on the effects of protein intake on infant birth weight. Maternal components of GWG, including fat-free mass (FFM) accretion (i.e., protein accretion), exhibit unique patterns of accretion during pregnancy, with varying effects on outcome (IOM, 2009). Abu-Saad and Fraser (2010) reviewed literature which examined the link between protein intake during pregnancy and adverse fetal outcomes. This review found sufficient evidence of a positive correlation between maternal protein intake and infant birth weight. They also noted dairy sources as being positively associated with infant birth weight in multiple studies. However, one study in this review pointed to both low and high protein intakes being associated with decreased birth weight.

Conversely, a prospective study of Canadian mothers found that protein intake was negatively correlated with birth weight (Stephens et al., 2014). A study of a multi-ethnic Asian population at 26-28 weeks gestation based on a 24-hour diet recall found that maternal macronutrient intake during pregnancy was not associated with infant birth weight (Chong et al.,

2015). Pereira-da-Silva et al. (2014) also found no association was found between absolute maternal intakes macronutrients and the body composition of neonates.

The current available research examining the direct link between protein intake, as well as specific amino acids, and infant birth weight is limited. Although the direct link between protein intake and fetal outcomes has been examined, the quality of the available studies provides insufficient evidence to make generalization about the relationship between these factors.

Chapter III: Methodology

This study was conducted as a secondary analysis from primary data collected to identify the relationship between maternal vitamin status and placental vascular development. The purpose of this chapter is to describe the methodology of this secondary analysis of including the research design, population and sample, data collection procedures, data collection instruments and data analysis.

Research Design

The primary study was a prospective longitudinal design. The purpose of the primary study was to identify the relationship of maternal vitamin status (low and adequate) with placental vascular development. Based on the anticipated development of preeclampsia in volunteers during the study period, the study allowed the opportunity to provide preliminary analysis of the relationship between maternal vitamin D status in pregnancy and preeclampsia. The nutritional intake data as well as biometric data which was collected for the mothers and fetuses provided the foundation for further research.

Population and Sample

Women within the northern plains of the United States were invited to participate through community recruitment methods. The Institutional Review Boards of the University of North Dakota and the cooperating health system approved the use of human subjects in this study and human subjects' protection was assured throughout the study. Interested individuals completed an application which was reviewed by the PI or designee. Eligibility criteria were confirmed in the women who responded to the advertisement. Inclusion criteria included women with no prior

deliveries, age 18 or over. These women whom have no prior deliveries (para 0) are said to be nulliparous. Additional inclusion criteria were English speaking and carrying a singleton pregnancy of less than 14 completed weeks gestation. Exclusion criteria included women who have had a prior completed pregnancy, women less than 18 years of age and women who are pregnant with more than one fetus. Enrolled women whose pregnancies terminated prior to 20 weeks of gestation were excluded, as preeclampsia is diagnosed in the second half of pregnancy.

Upon initial contact, an appointment with a member of the research team was made for eligible volunteers between 10 and 14 completed weeks of pregnancy. The PI or her designee provided eligible volunteers with the written consent statement. The purpose of this study, procedures involved, and expectations of volunteers were explained. Contact information for the PI was provided for follow-up at any time for questions or concerns. Eligible volunteers indicated consent by signing the consent form after all questions have been answered. A copy of the signed consent document was provided to the volunteer with the original kept for study documentation. Pregnancy was confirmed with a urine test completed at the initial appointment.

Sample and Data Collection

The analysis for this study included data from 65 women. Dietary intake data for protein and amino acids was collected during visits at times 1 (10-14 weeks gestation), 2 (22-26 weeks gestation) and 3 (32-36 weeks gestation) (Anderson, Ralph, Wright, Linggi, & Ohm, 2014). Data for dietary intake was based on a Food Frequency Questionnaire (FFQ) patterned after the Harvard Science FFQ format (Swensen, Harnack & Ross, 2001). The FFQ contains 78 food items with the natural portion size indicated for each (i.e. 1 cup of milk, 1 slice of bread). Each item on the FFQ was matched to food codes from either the USDA National Nutrient Database

for Standard Reference, Release 20 or the USDA Food and Nutrient Database for Dietary Studies 2.0 (Anderson et al., 2014). Codes for both databases were integrated into the onsite database for consistency. For each food item participants indicated their average consumption by marking 1 of 9 frequency categories which ranged from "zero per month" to "six or more times per day". This indicated frequency was then converted to account for daily intake. For example, if a participant indicated "1-3 per month" this was converted to 0.07 servings per day (2 servings per month).

Medical Record Abstraction

Demographic and birth outcome data was collected after pregnancy completion through medical record abstraction. The weight measurements were chosen based on the time point closest to the nutrient intake time. Weight measurements that occurred at a time point greater than 30 days from the respective intake date were removed resulting in the loss of six records.

Protection of Human Subjects

To ensure confidentiality of human subjects, all data sheets and response forms will be coded with a unique subject number. Upon complete collection of data, the PI maintaining linkage data shredded these documents. A password secure, confidential computer file containing this linkage is kept at the primary study's associated research center, but access will be limited to select staff members. This linkage is separate from data files and is kept for several reasons. Data will be kept in computer encrypted form and/or hard copy form for at least 3 years following completion of the study. Research data is stored separately from consent forms and subject personal data. Any paper containing identifiers or personal information will be shredded upon disposal. Other non-descript forms will be thrown away or recycled. Computer

media, such as magnetic tape or hard disks, will be erased and then reformatted using a low-level format to ensure erasure of sensitive data. CDs will be broken, then destroyed.

Analytic Plan

Pregnancy outcome data including weights, date of weight capture and other measures such as infant birth weight were available for 52 of the 65 women with corresponding intake data. Thus, we analyzed the 52 women with data for both measures. Demographic data was analyzed using descriptive statistics.

Spearman correlations were performed to identify a possible relationship between the intake of protein and amino acids at each time point (1, 2, and 3) on birth weight, trimester maternal weight gain, and total maternal weight gain. Our data was non-linear and violated the assumptions of parametric tests resulting in a nonparametric analysis. Spearman rank correlations were the most relevant method of analysis. Gestational weight gain at each of the three trimesters, total maternal weight gain as well as birth weight of the fetus were categorized into high and low groups.

Wilcoxon signed-rank tests were performed to identify group differences (high and low) in protein and amino acid intake and the resulting effect on gestational weight gain in each trimester, total gestational weight gain, as well as infant birth weight. Significance was determined at $p < 0.05$.

Chapter IV: Results

Introduction

This study seeks to examine maternal protein and amino acid intake on gestational weight gain (GWG) and birth outcomes across pregnancy. This chapter begins with an overview of the sample/population and instrument used. The remainder of the chapter is organized based on the specific research questions. First, we examine at the relationship between dietary intake of protein and amino acids and gestational weight gain, including total weight gain. Then we report on the relationship between both dietary intake of protein and amino acids and gestational weight gain on infant birth weight, respectively.

Response Rate of Sample/Population

Based on a total enrollment of 65 women, 86% (N = 55) were retained throughout the length of the study. Four participants of the study were lost to follow-up. Two participants left the study because they moved from the area. Another two participants were removed from the study following miscarriage. Additionally, one participant could not complete the study after changing to nonparticipating provider.

Representativeness of Sample

The study sample represents pregnant women in the northern plains of the United States who were recruited for the purpose of the primary researcher's study. Individuals were not recruited based on the specific purpose of this study. The primary study initially estimated a number of 100 volunteers needed for each of the two groups to achieve a power of 0.9. The final participant enrollment did not meet these estimates.

Reliability of Instrument

This study did not independently test the validity and reliability of this instrument. However, similar versions have been administered in studies which quantified nutrient intake in pregnant women (Anderson et al., 2014).

Research Questions

Dietary Intake of Protein and Amino Acids and Gestational Weight Gain.

There was no relationship between dietary intake of protein and amino acid intake and GWG. Results from our Spearman correlations showed no correlation between protein and amino acid intake and trimester weight gain or total GWG ($p \geq 0.45$). Based on results from the Wilcoxon sign-ranked tests, women in the bottom and top tertiles for trimester weight gain and total GWG did not significantly differ in protein or amino acid intake ($p \geq 0.33$).

Dietary Intake of Protein and Amino Acids and Infant Birth Weight.

Next, we examined the relationship between dietary intake of protein and amino acids and infant birth weight. Results from Spearman correlations revealed neither 1st, 2nd, nor 3rd trimester protein intake was associated with infant birth weight ($r = 0.10$, $p = 0.48$; $r = 0.20$, $p = 0.17$; $r = 0.05$, $p = 0.74$; respectively). Though it did not achieve a level of statistical significance, 2nd trimester protein intake showed the closest relationship to infant birth weight ($p = 0.17$). Of the 18 amino acids assessed, only cystine was marginally correlated with infant birth weight ($r = 0.27$, $p = 0.06$). See *Figure 1*.

Wilcoxon sign-ranked tests demonstrated no significant difference in 1st, 2nd, or 3rd trimester protein intake for women delivering infants with birth weight ≤3000 grams compared to those delivering infants with birth weight ≥3500 grams ($p = 0.32, 0.23, 0.50$, respectively).

Women delivering infants weighing ≤3000g had marginally lower 2nd trimester cystine intake than women delivering infants weighing ≥3500g (1.1 vs. 1.6 grams/day) ($p = 0.06$).

Summary of Chapter

In summary, there was no correlation between protein intake and trimester weight gain or total weight gain in our sample. There were no group differences in intake between those women with high gestational weight gain versus low gestational weight gain. In relation to birth outcomes, there was no significant correlation between trimester or total protein intake and infant birth weight. However, 2nd trimester cystine intake did show a marginal correlation. There were also no significant group differences in protein intake for high versus low infant birth weight. Comparably, there was a marginal correlation for group differences in 2nd trimester cystine intake and infant birth weight.

Chapter V: Conclusions and Recommendation

Summary of Findings

Though it did not achieve statistical significance, cystine showed a marginal correlation with infant birth weight. It shows no correlation with gestational weight gain. Maternal dietary protein intake, critical for optimal fetal growth and development, exceeded the Recommended Daily Intake (RDI) of 71 g/day for pregnancy in our sample limiting ability to determine impact on birth outcomes (IOM, 2006).

Limitations

This study should be replicated using a larger sample size. Additionally, it would be beneficial to compare group differences in outcomes for those who did not meet the RDI for protein in pregnancy versus those who did. The sample was located in a constrained geographical location and would better represent the overall population if participants were located from a more diverse region or multiple locations throughout the United States.

Administering a FFQ during pregnancy is a non-invasive method to track intake but has its limitations as well. Recalling one's diet over the last three months can be difficult for participants. Self-report methods for dietary intake such as the FFQ create a potential tendency towards reporting bias. Also, the cut off point for the time between intake data and maternal weight was 30 days potentially reducing the accuracy of associations between these variables.

Implications of this Study

Future studies examining variable cystine intake in pregnancy may identify influence on infant birth weight during critical periods of development. Additional studies may also examine the relationship between all three macronutrient intakes on birth outcomes across pregnancy.

In generating new knowledge, it would be beneficial to obtain biometric data and intake data during the same visit to ensure preciseness. With advancing technology, apps are now available to track one's intake and could potentially be used to retrieve intake data or recall dietary patterns for improved ease and accuracy.

Nurses should continue to educate women on appropriate GWG based on their individual pre-pregnancy BMI. Additionally, nurses should facilitate educating a more diverse community of women to strive for healthy lifestyle choices prior to attempted conception to improve pre-pregnancy BMI and nutrition.

In practice, nurses should strive for routine monitoring of GWG based on standardized WHO BMI cutoff points. Policies for the monitoring of GWG should be systematically implemented to prevent loss of potential data and results should be reported including in-depth demographic data. Further nursing research on the effects of nutrition and pregnancy outcomes is needed for all different ages, racial/ethnic groups and socioeconomic statuses.

We also recommend the development of a more in-depth food frequency questionnaire that would accommodate diets from different cultures and the increasing variety of foods commonly available in supermarkets today. Additionally, it would allow for more accurate reporting and less confusion for the participant.

Implementation

Monitoring GWG and nutrition throughout pregnancy is cost-effective and of virtually no medical risk to the mother or fetus. It is also feasible if the mother has frequent prenatal checkups, as this is something that can be done during every visit. However, there are also multiple potential barriers when implementing these recommendations into practice. A woman

might not know her exact pre-pregnancy weight or may not find out she is pregnant until her second trimester. These unpredictable factors make it difficult to measure weight gain in the first trimester alone. Additionally, they would prevent a woman from being able to participate in the entire length of a research study. Implementing a FFQ requires more effort and information from the participant and may evoke some discomfort when discussing food habits. This concerns could be addressed as needed by the staff or investigator. As with any change in practice, one will encounter resistance from the clinicians who are responsible for incorporating the new change. It is important to educate all staff or investigators on the reasoning behind the decision and how it benefits their organization and the patients.

The changing demographic of pregnant women in the United States requires novel research. The development of best practice guidelines for diet and weight gain in pregnancy across all races, ethnicities and socioeconomic classes will lead to better outcomes and healthier women and babies.

References

Abu-Saad, K., & Fraser, D. (2010). Maternal Nutrition and Birth Outcomes. *Epidemiologic Reviews, 32*, 5-25. doi: 10.1093/epirev/mxq001

Anderson, C. M., Ralph, J. L., Wright, M. L., Linggi, B., & Ohm, J. E. (2014). DNA Methylation as a Biomarker for Preeclampsia. *Biological Research for Nursing, 16*(4), 409-420. doi: 10.1177/1099800413508645

Barker, D. J., & Osmond, C. (1988). Low birth weight and hypertension. *BMJ, 297*(6641), 134-135. doi:10.1136/bmj.297.6641.134-b

Barker, D. J., Osmond, C., Winter, P. D., Margetts, B., & Simmonds, S. J. (1989). Weight In Infancy And Death From Ischaemic Heart Disease. *The Lancet, 334*(8663), 577-580. doi:10.1016/s0140-6736(89)90710-1

Chong, M. F., Chia, A., Colega, M., Tint, M., Aris, I.M., Chong, Y., Gluckman, P., Godfrey, K. M., Kwek, K., Saw, S., Yap, F., van Dam, R. M., & Lee, Y. S. Maternal Protein Intake during Pregnancy Is Not Associated with Offspring Birth Weight in a Multiethnic Asian Population. *The Journal of Nutrition, 145*(6), 1303-1310. doi: 10.3945/jn.114.205948

Cordain, L., Eaton, S. B., Sebastian, A., Mann, N., Lindeberg, S., Watkins, B. A., O'Keefe, J. H., & Brand-Miller, J. (2005). Origins and evolution of the Western diet: health implications for the 21st century. *The American Journal of Clinical Nutrition, 81*(2), 341-354.

Gargallo Fernández, M., Quiles Izquierdo, J., Basulto Marset, J., Breton Lesmes, I., Formiguera Sala, X., & Salas-Salvadó, J. (2012). Evidence-based nutritional recommendations for the prevention and treatment of overweight and obesity in adults (FESNAD-SEEDO

consensus document). The role of diet in obesity prevention (II/III). *Nutrición Hospitalaria, 27*(3), 800–832. doi: 10.3305/nh.2012.27.3.5679

Fogelholm, M., Anderssen, S., Gunnarsdottir, I., & Lahti-Koski, M. (2012). Dietary macronutrients and food consumption as determinants of long-term weight change in adult populations: a systematic literature review. *Food & Nutrition Research, 56,* 1-45. Retrieved from http://dx.doi.org/10.3402/fnr.v56i0.19103

Grotto, D., & Zied, E. (2010) The Standard American Diet and Its Relationship to the Health Status of Americans. *Nutrition in Clinical Practice, 25*(6), 603-612. doi: 10.1177/0884533610386234

Hanson, M. A., & Gluckman, P. D. (2015) Developmental origins of health and disease – Global public health implications. *Best Practice & Research Clinical Obstetrics and Gynaecology, 29*(1), 24-31. Retrieved from http://dx.doi.org/10.1016/j.bpobgyn.2014.06.007

Heude, B., Thiébaugeorges, O., Goua, V., Forhan, A., Kaminski, M., Foliguet, B., . . . Charles, M. A. (2011). Pre-Pregnancy Body Mass Index and Weight Gain During Pregnancy: Relations with Gestational Diabetes and Hypertension, and Birth Outcomes. *Maternal and Child Health Journal, 16*(2), 355-363. doi:10.1007/s10995-011-0741-9

Hunt, K. J., Alanis, M. C., Johnson, E. R., Mayorga, M. E., & Korte, J. E. (2012). Maternal Pre-Pregnancy Weight and Gestational Weight Gain and Their Association with Birthweight with a Focus on Racial Differences. *Maternal and Child Health Journal, 17*(1), 85-94. doi:10.1007/s10995-012-0950-x

Imdad, A., & Bhutta, Z. A. (2011). Effect of balanced protein energy supplementation during pregnancy on birth outcomes. *BMC Public Health, 11*(Suppl 3), 1-13. doi:10.1186/1471-2458-11-s3-s17

Medicine, I. o. (2006). *Dietary Reference Intakes: The Essential Guide to Nutrient Requirements*. Washington, DC: The National Academies Press. doi:10.17226/11537

Medicine, I. o., & Council, N. R. (2009). *Weight Gain During Pregnancy: Reexamining the Guidelines*. Washington, DC: The National Academies Press. doi:10.17226/12584

Johnson, J., Clifton, R. G., Roberts, J. M., Myatt, L., Hauth, J. C., Spong, C. Y., . . . Sorokin, Y. (2013). Pregnancy Outcomes with Weight Gain Above or Below the 2009 Institute of Medicine Guidelines. *Obstetrics & Gynecology, 121*(5), 969-975. doi:10.1097/aog.0b013e31828aea03

Leidy, H. J., Clifton, P. M., Astrup, A., Wycherley, T. P., Westerterp-Plantenga, M. S., Luscombe-Marsh, N. D., . . . Mattes, R. D. (2015). The role of protein in weight loss and maintenance. *American Journal of Clinical Nutrition, 101*(6), 1320S-1329S. doi:10.3945/ajcn.114.084038

Ludwig, D. S., & Currie, J. (2010). The association between pregnancy weight gain and birthweight: A within-family comparison. *The Lancet, 376*(9745), 984-990. doi:10.1016/s0140-6736(10)60751-9

Maslova, E., Halldorsson, T. I., Astrup, A., & Olsen, S. F. (2015). Dietary protein-to-carbohydrate ratio and added sugar as determinants of excessive gestational weight gain: A prospective cohort study. *BMJ Open, 5*(2), 1-9. doi:10.1136/bmjopen-2014-005839

Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2014). Prevalence of Childhood and Adult Obesity in the United States, 2011-2012. *JAMA, 311*(8), 806-814. doi:10.1001/jama.2014.732

Olafsdottir, A. S., Skuladottir, G. V., Thorsdottir, I., Hauksson, A., & Steingrimsdottir, L. (2006). Maternal diet in early and late pregnancy in relation to weight gain. *International Journal of Obesity, 30*(3), 492-499. doi:10.1038/sj.ijo.0803184

Pereira-Da-Silva, L., Cabo, C., Moreira, A., Virella, D., Guerra, T., Camoes, T., . . . Ferreira, G. C. (2013). The Adjusted Effect of Maternal Body Mass Index, Energy and Macronutrient Intakes during Pregnancy, and Gestational Weight Gain on Body Composition of Full-Term Neonates. *American Journal of Perinatology, 31*(10), 875-882. doi:10.1055/s-0033-1363502

Pitkin, R. M. (1976). Nutritional support in obstetrics and gynecology. *Clinical Obstetrics and Gynecology, 19*(3): 489-513.

Rodriguez, N. R., & Miller, S. L. (2015). Effective translation of current dietary guidance: Understanding and communicating the concepts of minimal and optimal levels of dietary protein. *American Journal of Clinical Nutrition, 101*(6). doi:10.3945/ajcn.114.084095

Santesso, N., Akl, E. A., Bianchi, M., Mente, A., Mustafa, R., Heels-Ansdell, D., & Schünemann, H. J. (2012). Effects of higher- versus lower-protein diets on health outcomes: A systematic review and meta-analysis. *European Journal of Clinical Nutrition, 66*(7), 780-788. doi:10.1038/ejcn.2012.37

Siega-Riz, A. M., Viswanathan, M., Moos, M., Deierlein, A., Mumford, S., Knaack, J., . . . Lohr, K. N. (2009). A systematic review of outcomes of maternal weight gain according to the

Institute of Medicine recommendations: Birthweight, fetal growth, and postpartum weight retention. *American Journal of Obstetrics and Gynecology, 201*(4). doi:10.1016/j.ajog.2009.07.002

Stephens, T. V., Woo, H., Innis, S. M., & Elango, R. (2014). Healthy pregnant women in Canada are consuming more dietary protein at 16- and 36-week gestation than currently recommended by the Dietary Reference Intakes, primarily from dairy food sources. *Nutrition Research, 34*(7), 569-576. doi:10.1016/j.nutres.2014.07.001

Swensen, A. R., Harnack, L. J., & Ross, J. A. (2001). Nutritional Assessment of Pregnant Women Enrolled in the Special Supplemental Program for Women, Infants, and Children (WIC). Journal of the American Dietetic Association, 101(8), 903-908. doi:10.1016/s0002-8223(01)00221-8Tabatabaei et al. (2011)

Who, J., & Consultation, F. E. (2003). Diet, nutrition and the prevention of chronic diseases. *World Health Organ Tech Rep Ser, 916*(i-viii).

Wycherley, T. P., Moran, L. J., Clifton, P. M., Noakes, M., & Brinkworth, G. D. (2012). Effects of energy-restricted high-protein, low-fat compared with standard-protein, low-fat diets: A meta-analysis of randomized controlled trials. *American Journal of Clinical Nutrition, 96*(6), 1281-1298. doi:10.3945/ajcn.112.044321

Tables

Table 1

Distribution of Median Nutrient Intake by Trimester

Median Intake	1st Trimester	2nd Trimester	3rd Trimester
Protein (g)	86.72	83.20	86.58
Cystine (g)	1.38	1.38	1.32
Tryptophan (g)	0.99	0.91	0.95
Threonine(g)	3.05	2.92	2.95
Isoleucine (g)	3.95	3.51	3.86
Leucine (g)	6.89	6.49	6.86
Lysine (g)	6.14	5.34	5.91
Methionine (g)	1.90	1.73	1.87
Phenylalanine (g)	3.84	3.70	3.80
Tryosine (g)	3.23	2.93	3.15
Valine (g)	4.56	4.17	4.56
Arginine (g)	4.08	4.15	4.16
Histidine (g)	2.43	2.20	2.32
Alanine (g)	3.61	3.64	3.69
Aspartic acid (g)	7.59	7,45	7.52
Glutamic acid (g)	16.48	15.73	16.41
Glycine (g)	2.95	2.98	3.08

Proline (g)	6.32	5.91	6.18
Serine (g)	4.05	3.89	4.15

Table 2

Distribution of Birth Weight and Total Gestational Weight Gain between 1st and 3rd Trimesters

Outcome	Sample Size	Mean	Standard Deviation	Minimum	Maximum
Birth Weight (g)	52.0	3311	549.1	1429	4774
Total GWG (lbs)	51.0	21.8	9.2	-2.0	44.0

Table 3

Distribution of Gestational Weight Gain by Trimester

Trimester	Mean Weight Gain (lbs)	Standard Deviation	Minimum	Maximum
2nd Trimester	9.0	5.8	-5.2	20.6
3rd Trimester	14.1	7.1	0.0	32.0

Figures

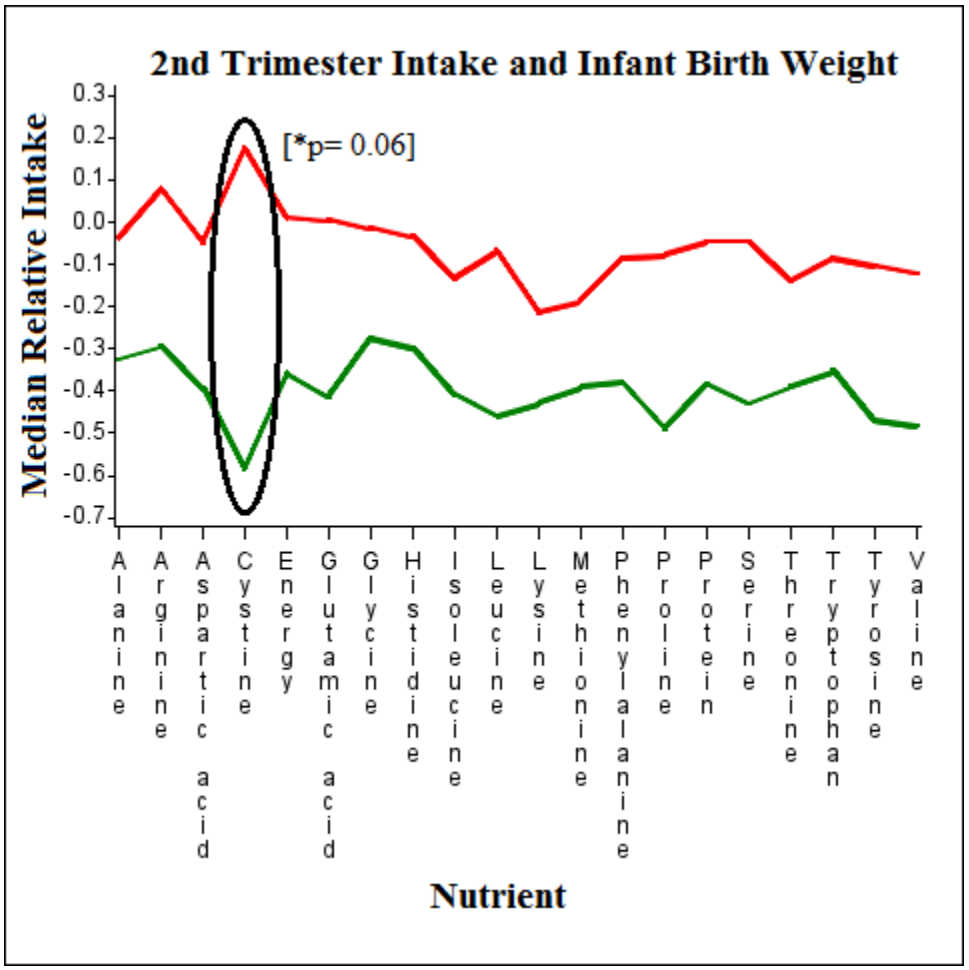

Figure 1. 2nd Trimester Intake and Infant Birth Weight

Note: *Green line indicates infant birth weight ≤3000g; Red line indicates infant birth weight ≥3500g